one takes its place, situated between the other two (Plate 5, fig. 10). This band is the most pronounced and the best defined one in the whole series, and only becomes visible on the photographic plate in excessively dilute solutions, so dilute that one might say the solution was colourless to the eye when viewed by transmitted light.

Phylloporphyrin and Hæmatoporphyrin.

On comparing the spectra of phylloporphyrin and hæmatoporphyrin in this region, and also those of their hydrochloric acid compounds (Plate 3, figs. 6, 7, 8, and 9), it was found that hæmatoporphyrin gave only a single band, but situated in the same position as the double one of phylloporphyrin. On this point the results of my experiments differ from those of Tschirch, who, as stated above, found in both a *single* band occupying the same position. In the hydrochloric compounds of hæmatoporphyrin, however, a single band of the same pronounced character as that in phylloporphyrin was found, the one in hæmatoporphyrin, as will be seen from the figures, being slightly shifted towards the red end of the spectrum, which is interesting from the fact that just in the same way are the bands in the visible region of the spectrum of these two compounds shifted, this constituting their only spectroscopic difference.

In conclusion, my thanks are due to Dr. E. Schunck and Dr. L. Marchlewski for the valuable assistance they have given me in many details in connection with this investigation.

I hope in a further paper to investigate more particularly the spectroscopic behaviour in the same region of the spectrum of the yellow colouring matter accompanying chlorophyll in leaves and allied colouring matters obtainable from other sources than the leaf, for instance, carotin.

"On Photographic Evidence of the Objective Reality of Combination Tones." By R. W. Forsyth, A.R.C.S., and R. J. Sowter, A.R.C.S. Communicated by Professor Rücker, Sec.R.S. Received March 29,—Read May 5, 1898.

[Plates 6, 7.]

In the following paper we propose to describe a series of photographs which prove the objective reality of difference and summation tones. The work was suggested to us by Professor Rücker, and we have used the method of detecting these tones which has been described by Rücker and Edser in the 'Philosophical Magazine' for April, 1895.

The resonator they employed was a tuning fork. On to one prong of the fork was fixed a mirror, which was made one of a system by which Michelson's interference bands were produced. To the other prong was attached a wooden square of larger area, but of the same weight as the mirror. The fork was then compared with a König standard fork and its frequency adjusted to 64. The notes were produced by a Helmholtz wind siren placed between a wooden pyramidal tube and a large König resonator tuned to 64. The narrow end of the pyramid was placed about half an inch from the wooden square attached to the resonating fork.

Throughout the experiments we used blue light, obtained by passing a beam from an electric lamp through a cell containing an ammoniacal solution of copper sulphate. A slit about 2 inches long and one-twentieth of an inch broad was cut out of a piece of tin-foil pasted on glass, and was placed horizontally across the middle of the bands, so that the bright and dark bands appeared as bright and dark spots respectively.

In our earlier experiments, we took photographs upon flexible film fastened by india-rubber bands to a rotating drum. A ball shutter, such as is used in instantaneous photography, was employed. Working at night, after the traffic had subsided, the bands in their normal condition were perfectly steady. On taking a photograph, each bright band produced a perfectly straight line upon the rotating film, and the whole picture was made up of a series of parallel straight lines.

On sounding a 64-fork in the vicinity of the apparatus, the mirror is set in motion by resonance and thus the bands execute harmonic motions, with a frequency of 64, about their mean positions. The general appearance as then seen by the eye is a blue blur. When this blur was photographed by means of the slit and rotating drum, we obtained a series of sinuous lines. To prove that the frequency of these curves corresponded to a note of 64 vibrations per second, we made observations on the rate of turning of the drum. The following are some of the actual figures obtained:—

Circum. of drum = 31·5 cm. 100 revs. in 19·5 secs.
Wave-length = 2·53 cm.

$$\text{No. of vibns. per sec.} = \frac{100 \times 31{\cdot}5}{19{\cdot}5 \times 2{\cdot}53} = 63{\cdot}9.$$

We thus obtained a series of photographs of what may be called the difference and summation curves, which were exhibited in a preliminary communication read by Professor Rücker at the recent meeting of the British Association held in Toronto.

The details of the method now employed are different, and we

venture to think much better suited for obtaining good photographs, though the drum enabled us to determine the frequency of the oscillation more easily. When the drum was used, it was inconvenient to take more than one photograph on the same film, and moreover, it was impossible to use plates, which in some respects have advantages over films.

Having satisfied ourselves by means of the drum, that the frequency of the curves we obtained corresponded to 64, we had recourse to a sliding plate arrangement fitted with an automatic shutter. The sliding piece is capable of carrying 3 feet of plate 2 inches in width, and the shutter is so arranged that any 6 inches of the plate can be exposed at will. With one filling of the slide, it is therefore possible to take six photographs.

Our first effort was to obtain photographs of the steady bands when no sounds were produced. We have taken many of these, and reproduce one of them in (Plate 6) fig. 1.

Fig. 2 shows a photograph taken when a 64 fork was sounding rather loudly.

Fig. 3 shows an extraneous disturbance produced by the slamming of a door. It is evident that the vibrations are compound and, in part at all events, forced. We then proceeded to obtain the difference-tone. The frequencies of the two notes used were 256 and 320, and these were produced as by Rücker and Edser with a Helmholtz double wind siren. The 12 row of holes was tuned to a 256-fork, and then to produce the 320-note the 15 row of holes was opened.

Fig. 4 shows a photograph taken when the 256-fork was sounding, and when the siren was sounding in unison with it, the 12 row of holes being open. It will be seen that the bands are steady. There is a slight vibration present, probably due to the disturbance produced by the blowing of the bellows.

Fig. 5 shows a photograph taken immediately after the foregoing one, upon the same plate, and under exactly the same conditions with the single exception, that the 15 row of holes was opened and the 320-note therefore sounding in conjunction with the 256. The objective reality of the difference-tone is clearly proved. This experiment has been repeated on several occasions and with different notes, and we have obtained many photographs demonstrating the vibratory motion which is given to the bands by the difference-tone. In all cases, we have proved that the separate notes sounding alone produced no effect upon the bands.

Fig. 6 (Plate 7) is another photograph of the effects produced by a difference-tone.

It will be observed in these two photographs, that although the chief effect is that due to the sounding of a 64-note, there is super-

Fig. 1.

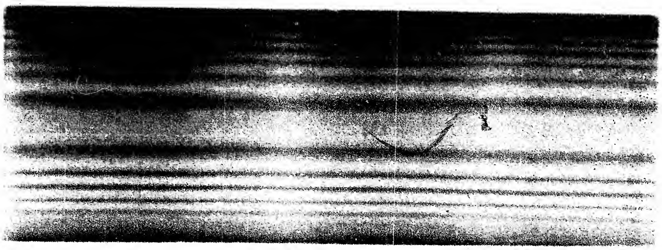


Fig. 2.

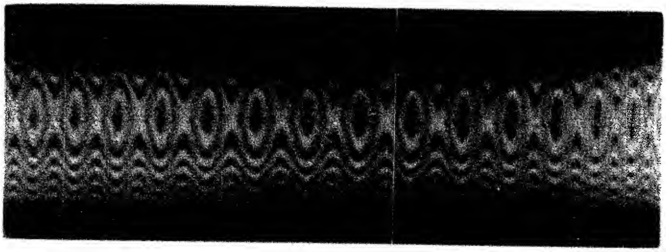


Fig. 3.

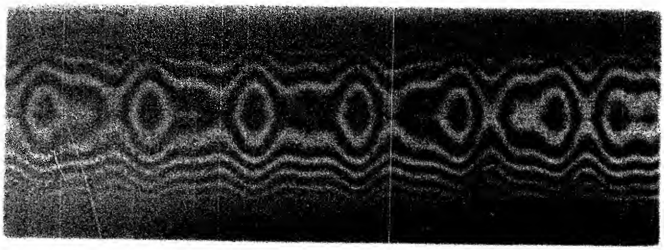


Fig. 4.

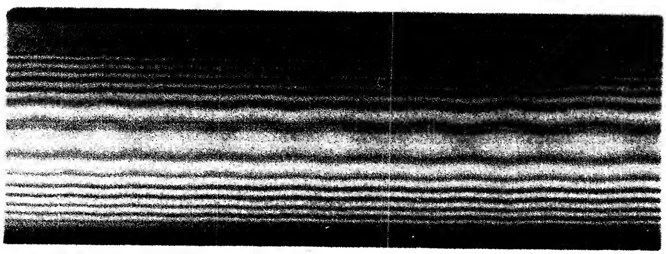


Fig. 5.

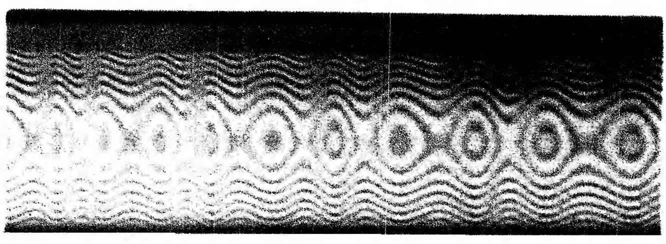


Fig. 6.

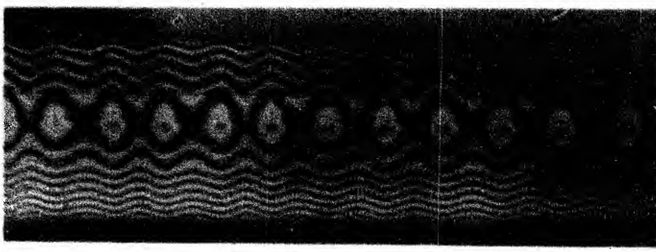


Fig. 7.

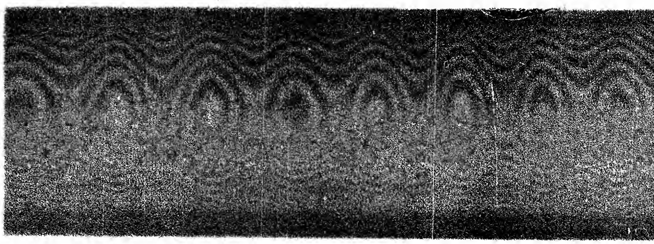


Fig. 8.

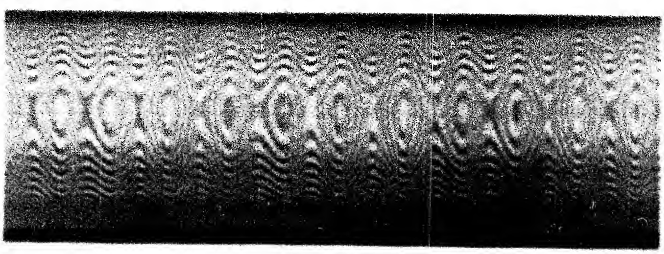
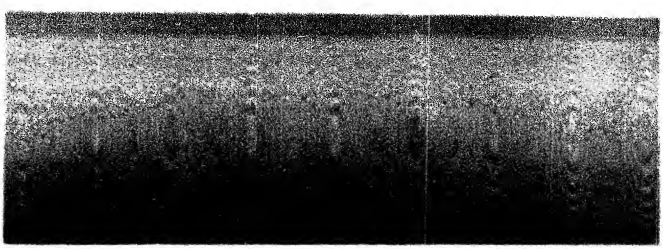


Fig. 9.



imposed upon this some other disturbance which causes a slight departure from the perfect regularity of the curves. This disturbing effect is probably due to the fact, that, as it is difficult to keep the pitch of the notes given by the siren absolutely constant, they had departed somewhat from their proper values at the moment when the photograph was taken, and thus forced vibrations of a pitch slightly different from that of the tuning fork were added to those corresponding to its natural period.

Having finished experiments on the difference-tone, we proceeded to photograph effects produced by the summation tone. The two notes used were obtained from the 9 and 12 rows of holes of the upper box of the Helmholtz double wind siren. It is easily seen that, to give a summation tone of 64, the disc must be revolving $64/(9+12) = 3{\cdot}048$ times per second. To obtain this rate of rotation we used a stroboscopic method. On the upper surface of the lower box of the siren, we affixed a star-like disc with 18 rays, and viewed it through slits carried by a fork having a frequency of 27·4.

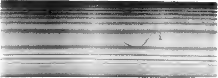
When the star appears stationary, the disc is revolving at the desired rate, for $18 \times 3{\cdot}048 = 27{\cdot}4 \times 2$ approximately.

We have taken photographs of the steady bands when the siren has been going at the proper speed, and one set of holes open only. These are exactly like the steady bands obtained in the former cases. On sounding the two notes together the summation tone is produced, and we have photographed it in the manner already described. Figs. 7, 8, and 9 show some of the photographs obtained.

In fig. 9, where the amplitude of the vibration of the bands is large, the plates used were not sufficiently sensitive to photograph them when moving through their mean positions. When the bands are in their extreme position and therefore at rest, the exposure is inversely proportional to the velocity of the plate. But when the bands are passing through their mean position, the exposure is inversely proportional to the velocity found by compounding the velocity of the plate with the velocity of the bands in a direction at right angles. If the amplitude is large enough, this velocity may be so great as to render the time of exposure too small to affect the plate. This phenomenon is slightly noticeable in fig. 5, and is very well marked in figs. 8 and 9.

In conclusion, we wish to thank Mr. Cameron for assisting us in taking some of the later photographs, and Mr. Chapman for the help he has given us in preparing the lantern slides and prints.

Fig. 1.



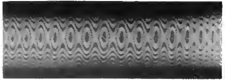


Fig. 2.

Fig. 3.

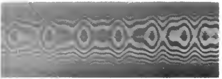


Fig.
4.

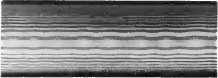


Fig 1.

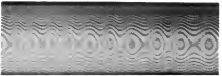


Fig. 6.

Fig. 7.

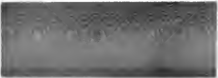


Fig. 8.

Fig. 9.